TECHNICAL UNIVERSITY OF LIBEREC
Faculty of Textile Engineering

Reinforcement of River Bank using Non-woven

Master Thesis

Study programme:	N3106 Textile Engineering
Study branch:	Nonwoven and Nanomaterials
Author:	**Shriram Rajendra Chougule**
Thesis Supervisors:	Ing. Jiří Chvojka, Ph.D. Department of Nonwovens and Nanofibrous materials

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Name and surname: **Shriram Rajendra Chougule**
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3. Elaborate Experimental Part regarding to theory
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1. KELLIE G. : Advances in Technical Nonwovens, Woodhead Publishing, 2016, ISBN-978-0-08-100575-0
2. FANGUEIRO R., RANA S. : Advances in natural fiber composites, Springer, 2018, ISBN-978-3-319-64640-4
3. DAS D., POURDEYHIMI B. : Composite nonwoven materials, Woodhead Publishing, 2014, ISBN-9780857097705
4. EICHHORN S., HEARLE J., JAFFE M. and KIKUTANI T. : Handbook of textile fiber structure, Woodhead Publishing, 2009, ISBN-9781845697303

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L.S.

Ing. Jana Drašarová, Ph.D.
Dean

Ing. Jiří Chvojka, Ph.D.
Head of Department

Liberec January 6, 2020

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ABSTRACT

When a river bank collapses the water takes away valuable land, cultivable land and demolishes cities build on its bank. It causes devastation and misery to the development done over the years ruining the human lives. The protection of river bank is difficult and costly piece of work. The main reason for the riverbank collapse is the soil erosion. Until now many methods of protection are utilized to reinforce the river bank. The use of nonwoven aquadesk for the reinforcement is the main objective behind this study. The methodology to produce aquadesk and the practical way of applying the aquadesk is found out in this dissertation.

Various strategies practised related to reinforcement have been studied in detail and discussed. Implementing those methods with current aquadesk and development possibilities are considered. The results and discussion in this diploma thesis will help in further study and expanding the scope for reinforcement of river banks.

Keywords: Riverbank, Soil Erosion, Reinforcement, Nonwoven, Aquadesk.

ABSTRAKT

Nezpevněné břehy řeky se při povodni zhroutí, voda odnáší půdu, obdělávatelnou půdu a působí místní erozi. Města postavená v blízkosti řek jsou devastována. Záplavy a povodně v průběhu let ničí majetek i lidské životy. Ochrana břehu řeky je obtížná a nákladná činnost. Hlavním důvodem kolapsu břehů vodních toků je eroze půdy. K posílení břehů řek se používá mnoho známých způsobů ochrany proti erozi. Hlavním cílem této práce je využití textilního netkaného materiálu Aquadesk pro vyztužení a zpevnění břehu. Metodika výroby Aquadesku a praktické způsoby aplikace těchto materiálů jsou uvedeny v této diplomové práci.

V této práci byly podrobně studovány a diskutovány různé strategie uplatňované v souvislosti se zpevněním břehů. Je zde zmíněna úvaha o implementaci možných metod se současnými materiály a možnostmi dalšího vývoje. Výsledky a diskuse uvedené v této diplomové práci vedou k možnostem zlepšení posílení břehů řek před erozí.

Klíčová slova: Břeh řeky, Eroze půdy, Výztuž, Netkaná textilie, Aquadesk.

Contents

ABBREVATIONS

%	Percentage
°C	Degree Celsius
µm	Micrometer
cm	Centimeters
CO_2H	Carboxyl group
CO-O	Ester group
G/m2	Grams per square meter
ISO	International Standards Organisation
M/s	Meter per second
Mm	Millimeters
Mm/min	Millimeter per second
MPa	Mega Pascal
N	Newton
NaOH	Sodium Hydroxide
OH	Hydroxyl group
PET	Polyethylene terephthalate
PLA	Poylactic acid
PP	Polypropylene
rPET	Recycled polyethylene terephthalate
TRM	Turf reinforcement fabric
UV	Ultraviolet
W	Weight of sample in grams per square area
WAG	Water absorbing geo-composite
Wt%	Percentage by weight

CHAPTER 1

INTRODUCTION

1.1 General

Soil and water relations are considered as an important interaction in all times. Water is origin of life but is also dangerous when it comes into a limitless amount. However humans have always been working on using water to fulfil their needs and also to face its worst form during floods in rivers [1].

During floods it is necessary to protect the river banks from erosion. However as erosion causes loss of top layer of soil which is the most productive part of soil in crop production. Also it causes the rise of water level which further increases the risk of floods. Hence it has become necessary to keep water in certain boundary to avoid any disaster [1].

Till now human kind have seen number of tsunami events in past in which nature has clearly revealed the power of water. In such cases not only it costs human life but also tremendous loss of land and property. Apart from tsunami waves, water has caused damaged in form of rain when there is too much of it. Numerous events of landslides and mud avalanches accounts for lives and destroyed property due to heavy rains [1].

To avoid any disaster caused by water, definite structures are needed to get steady river banks right from selecting the suitable material, their designs and proper implantation. To aid this, till now textiles applied under soil also called as 'Geo-textiles' have been proved useful to support and even improve the behaviour of soil. As these textile materials are able to provide high strength and flexibility along with drainage, durability and even controlling erosion of soil [1].

So to keep water in certain boundary, strength is required against water pressure and flow. This can be done either reducing the effect of water on banks or by improving the resistance of ground against water effects. In this method, the structure and stability of soil on the ground is improved by the use of geo-textile material in form of woven or nonwoven fabric. In this project work we will concentrate on nonwoven geo-textile fabric, its production and how it can be used for reinforcement of riverbank [1].

1.2 Background of the study

Water is vital for life and the main source of fresh water for humans and plants and animals is through rivers and canals and reservoirs. Knowing importance of water humans started to migrate towards water bodies for housing and agricultural purposes. Hence rivers that are passing through populated areas requires protection of river banks to minimize the threat of erosion and floods also to minimize the loss of property and life. Various techniques and materials are been used to provide strength to the riverbanks and reinforce them. The soil bioengineering technique is mainly famous for using plants or its parts like roots, stems by planting, cutting or spreading them on various portions of river bank in presence of solid stabilisation methods such as stones, logs, fibre roll, etc [2]. Due to eco-friendly nature, cost effective behaviour and serviceability, live stakes and vegetation geo-grids are been used in large numbers for reinforcement of river bank in last few decades [3].The conventional methods were to build walls where the water flow is strong, also placing large rocks, trees, etc. Also some structural measures were taken to reduce the soil erosion and also to bring relief to flood prone areas like to create a diversion of part with high flow of water to another river or a small reservoir, embankment of river, stones and concrete revetments, construction of gyrones & spurs and also using vegetation and recently using technical textiles such as geo-textile fabric, geotubes and geo-bags [1, 3].

1.3 Objective of the study

Due to the ongoing worldwide pandemic the lockdown in the Czech Republic in 2020 caused the countrywide universities to prohibit the working of students at their respective college. The labs at Technical University of Liberec were also closed due to restrictions hence this thesis will be explained on a theoretical basis. The objective of the study is to get knowledge about the various processes, methods and techniques used to reinforce the river bank. The main focus will be on getting introduced to the nonwoven technique. There production method with studying the properties through various testing method. Using nonwoven strengthening the river banks and with that, techniques used for installing the material in the river banks and required preparation for that. A deep research on current methods used for reinforcement is done and ways to implement the methods in current aquadesk is proposed.

1.4 Organisation of the thesis

The thesis is divided into eight chapters. Each chapter is an individual part of the study. The chapter are further divided into sub-branches based on the requirement of study. A brief outline is presented below in this thesis-

Chapter 1 depicts the need and importance of protecting the river bank during floods and rainfall. The chapter also states the background and objective of the study.

Chapter 2 reviews the literature and past studies on riverbank protection works with various alternatives to explore innovative ways for reinforcement

Chapter 3 explains the main cause for river bank failure and techniques used to protect and strengthen the river bank.

Chapter 4 describes the detailed Nonwoven manufacturing method starting from fiber selection to bonding technique.

Chapter 5 explains the plan of work and experimental work. Also describes the testing apparatus and improvisation techniques.

Chapter 6 presents the result of the theoretical study in brief possibilities based on the study.

Chapter 7 represents the discussion of the thesis.

Chapter 8 shows the references to the journals, books, websites, articles used for building up this thesis work.

CHAPTER 2

LITERATURE REVIEW

2.1 General

In this chapter we will discuss the relevant research done on using various textile materials using in riverbanks. Main focus will be on nonwoven geotextile. Also we will see different methods, materials and techniques used for bank protection. Since this project is on a theoretical basis we are discussing various techniques used prior and how we can use them in our product to achieve good results.

2.2 Research

i. **Ashis Mitra** in his review for geotextiles and their applications in engineering studied various uses of geotextiles and also stated that geotextile usage is more economical as compared to other structural measures. His paper highlighted the vital role of geotextile in erosion control and slope stabilization. He stated various techniques of producing geotextile from which nonwoven geotextile readily provide stable water flow and helps in soil stabilization. According to his evaluation, the mechanical properties of nonwoven geotextile made them perfect for reinforcing the river bank slope preventing the collapse of soil walls and steep slope [4]. The simple way of how geotextile can reinforce the soil walls is shown below**:-**

Figure 2.1: - Geotextile Reinforcement [4]

ii. **Hongling Zhang** from China made a research study on soil bioengineering technique to improve the riverbank stability and work on soil erosion problems on slopes. He conducted a experiment by using three different ways to improve the soil stability in Liaohe river in China. The common thing used in all three methods was vegetation named Salix integra which is a species known for higher growth, durable, cost effective and was effective in preventing the slope erosion developing strong roots. The three methods were using the same vegetation plant with different methods. First was using the plant species with nonwoven fabric, second method included perennial herb stems that are easy to grow combined with Salix integra and third methods consisted of using like takes i.e. branches of trees with the same vegetation. The course of the experiment was 4 years. The testing included study of vegetation coverage. It was concluded that the surviving rate of the vegetation at the slope was high in case of nonwoven as compared to fiber roll and live stakes. When the site was observed it was clear that the most growth and coverage which was 91% was observed with nonwoven [5]. The pictorial view of the vegetation coverage using nonwoven is shown below: -

Figure 2.2: - Vegetation coverage before and after using nonwoven [5]

iii. **D.T. Bergado**, Professor of Geotechnical Engineering from Thailand worked on the role nonwoven geotextile as a reinforcement agent after incidents of extreme slope failure and soil erosion in a river in Thailand. Firstly he studied the main cause of the slope failure which was heavy rains. The study project used nonwoven geotextile with gabions and mattresses. The test included the study of slope stability. The slope stability analysis was carried out using a computer program STABL6 [6].

D.T. Bergado stated that nonwoven acted as a filter and reinforcement element and the test results from computer slope analysis showed the slope after use of nonwoven geotextile was stable even under most critical conditions. So the material was used practically in the river and was functioning well [6].

iv. In research study on nonwoven mat used for vegetation body by **Wolfgang Behrens**, he invented mat to be used specifically for vegetation purpose which can serve for building roofs. The nonwoven mat made by him consists of two layers in which the top layer consisted of fertile soil or nutrients substrate like nitrogen, phosphorous that promotes growth while the bottom layer was made to store water and allow the roots of plant to penetrate through it. These two separate mats are then connected to each other by either stitching by threads for by bonding method. The blend of natural and synthetic fibres can be used for the production but most advantageous proportion was 60% synthetic and 40% natural fibres. The test resulted that this blend ratio at 1200 g/m^2 can hold upto 9 liters per square meter [7].

v. **D. Shercliff** researched the design methods for using geosynthetics for erosion control on river banks. The study of turf reinforcement mattresses (TRM) stated that when the water flow is steady or slow, the soil is still prone to get eroded. A natural way to prevent this is naturally vegetation which can be established and conserved using TRM. They prove beneficial for reinforcing the roots of the vegetation and also serve as covering for grass. The structure of TRM resembles a three dimensional polymer matrix. He also studied about composite geo-mattress made from two layers of geotextile fabric sewn to produce long tubes which are to be filled with sand. It composed of woven geotextile at the back side for providing reinforcement and fixing while the front side is a composite of both woven and nonwoven geotextile. The nonwoven geotextile promotes growth of vegetation [8].

vi. "The Roles of Geotextile in Erosion & Sediment Control" by **Nasrin Ferdous** and **Reashad Bin Kabir** stated the importance of erosion control in the river bank to avoid any disaster. Hence to produce a nonwoven geotextile that can withstand and carry out the main function i.e. soil erosion it is necessary to study the parameters deciding the design of geotextile and steps to use the produced fabric effectively [9].

Since the types of geotextiles are vast it is vital that the fabric chosen serves its purpose. The design, requirements solemnly depends on the application type. Hence for reinforcement and erosion control the fabric must have high tensile properties with great water retention quality. Also they must be durable enough providing enough resistance against chemical, biological and thermal effect. The site preparation includes clearing of slope from unnecessary objects like stones, weed, roots and other to make surface smooth and free of any obstructions before laying the fabric. Overlapping of three feet must be done for adjacent sheets as well as at the end of the roll. The overlaps are to be sewed or stapled or welded together wherein sewing is most preferable and carried out using high tensile yarns made from PET, PP or nylon. While on the slopes the geotextile if fixed to the ground by using steel pins/needles. Their placing depends on the slope structure while the size is influenced by the hardness of the soil [9]. Simple considerations while fixing the geotextile on the slope is shown below: -

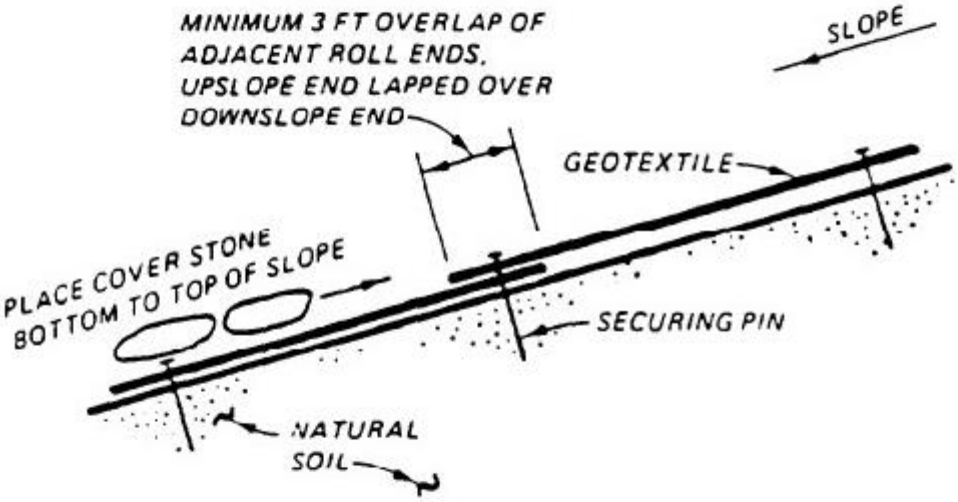

Figure 2.3: - Slope profile after geotextile placement [9]

vii. **Mr Jing-Chzi Hsieh** along with others produced a vegetation board for protection of the land surface from erosion and landslides. They made a nonwoven board composed of mainly biodegradable polylactic acid and low melt polylactic acid fibres mixed with cotton and far-infrared fibers. The samples were produced varying the ratio of far infrared fibers keeping other three constant. Web was bonded using needle punching method [10].

The PLA and low melt PLA formed the main body with far infrared fibers radiating 4 to 14µm which promotes growth of plants whereas cotton served the purpose of water absorption. The grass used for vegetation was Centipede grasses. The produced material was tested for basic properties along with the plant growth evaluation. Results showed that the samples containing 10 wt% and 50 wt% the amount of plants grown were similar but the length of the plant with 50wt% was higher than with 10wt% [10]. Following figure shows the growth with 10 and 50 wt% respectively: -

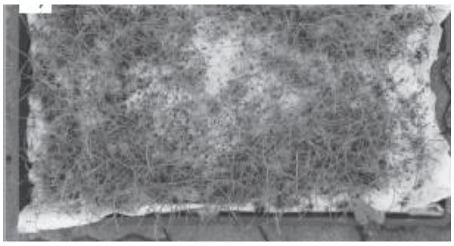

Figure 2.4: - 10 wt% Far Infrared fibers [10]

Figure 2.5: - 50 wt% Far Infrared Fibers [10]

This was because the rays from fibers form resonance with water molecules that activated the water molecules in plants which resulted into better plant growth. Hence it was concluded that with more amount of far infrared fibers the plant growth is better [10].

viii. **Abdelmalek Bouazza** studied the water retention property of nonwoven polyester geotextile. The nonwoven was produced using needle punching method and was tested for water retention using hanging column test for cross plane and by capillary rise action for in plane direction. The test results concluded that the in plane fabric showed no capillary rise stating that the in plane was more hydrophobic than cross plane during the wetting conditions. While for cross plane it was concluded that pore size and porosity determined the water flow through the material [11].

For material with high porosity, de-saturation i.e. drying/removal of water can be done at low suction/force, while for small opening size and porosity needed higher suction for de-saturation [11].

ix. **S. Premkumar** and **K. Thangamani** studied the water retention properties of woven and nonwoven fabric made from Jute used for curing of concrete. Curing process of concrete is the treatment that imparts strength in the concrete. In curing process the concrete is wrapped either in woven or nonwoven and is kept 7 days. In these days continuous water is sprayed on the fabric to make sure uniform distribution of water throughout the curing process. The water holding capacity is measured by prewetting the fabric first and then supplying known amount of water and collecting the droplets in a beaker below the fabric. The holding capacity was measured using following formula: -

$$A4 = A1 + A2 - A3 \ldots\ldots\ldots\ldots\ldots \text{eq (1)}$$

Where, A4 – Water holding capacity, A1- Water used for pre wetting, A2- water supplied, A3- water collected in beaker. The results from the testing proved that the nonwoven fabric had better absorbency and retention properties as compared to woven fabric with same mass per unit area. On average the water holding capacity of nonwoven was 20% more than the woven material. This was because of porous structure of nonwoven which has extra pore volume that makes it possible to hold more water. Hence the concrete also showed better curing resulting to increase in 11% compressive strength with nonwoven curing as compared to concrete cured with woven fabric [12].

x. **Jia-Horng Lin** with the help of other researchers studied the soilless culture medium. This medium makes it possible for plants to grow without soil and is usually made up of coconut and PP fibers. This soilless media helps when used on walls helped in reducing the temperature of buildings and also gives sound insulation. Also promoting green areas and reducing green house effects. The study was devoted to produce soilless media from mixing polyester and low melt polyester fibers and thermally bonding those [13].

The effect of change in the ratio of low melt PET bicomponent fibers on water content and water retention was observed and results were carried out. The results proved that with increase in the content of low melt PET fibers the pore size decreases which allow water to create enough surface tension force on the fibres restricting them to drip. Hence bi-component fibers help in increasing the water content and water retention property [13].

xi. **Shanthi Radhakrishnan** in their study remarked the importance of recycled polyester over virgin polyester. In their study she stated the serious effects of virgin polyester and how this effect can be reduced by re-using the already existing polyester. According to the study, over the years the production of polyester fiber has greatly impacted the environment as large numbers of petrochemical are used for its production. Also the manufacturing method requires huge quantity of water. Among natural fibers where cotton stands on top for energy consumption, later it was revealed that polyester takes about 40% more energy than cotton. The developing countries producing majority of polyester don't have serious regulations when it comes to treating the effluents and chemicals released from the industries which leads to environmental problems polluting land and water and as well affecting ecology. As polyester is non-degradable it was serious concerns to reduce the use of polyester with researching new techniques for recycling the waste generated [14].

Studies revealed that recycled polyester properties resemble that of virgin polyester except for strength because of recycling process. In the recycling process the waste polyester bottles are used to produce rPET fibers by using chemical or mechanical procedure. The polyester flakes obtained from waste bottles can be used for making staple polyester fibers. Presently, there are various case studies for recycling the polyester. Some of them use de-polymerization or special enzymes or solvents. While mechanical recycling contains sorting, cleaning, grinding and melting steps [14]. The process is shown below: -

Figure 2.6: - Mechanical Recycling of PET [14]

The main advantages of rPET over virgin polyester are effective reduction in carbon emissions due to recycling, it also reduces the pollution created by plastics, and the properties are similar with slight reduction in strength because of recycling. Also recycling could open new opportunities in research field in finding new applications [14].

xii. Group of researches including **Daria Marczak** worked on water absorbing geocomposite also known as WAG. They produced various needle punch nonwovens using wool, linen and used the geotextile for vegetation. In one sample they wool was reinforced using biodegradable jute mesh. This high absorbent material was effective in sustaining the vegetation for at least one season till the plants are grown enough and later was able to decompose in the soil increasing the nutritional value of soil. The experiment included creating of geotextile samples and using them for vegetation. After the vegetation season the geotextile were cleaned to eliminate plant roots, soil and testing was performed. The effect of time on biodegradation was evaluated by physical and mechanical tests of geotextile. After 6 months of functioning the wool and jute geo-composite showed lenient degradation. The moisture content was found high and also the root growth was intensive. It was found that wool degrade slowly and in presence of high strength jute mesh it generated good conditions for growth of plant and it extended the period of biodegradation. This time period was enough for plant growth and can be used for protection of slopes [15].

xiii. **Ebru Çelikten** developed a air-laid nonwoven using latex bonding. The main raw material used for air-laid was wood pulp fibers and the latex used was acrylic. Samples were made by varying ratio of latex used by keeping the ratio of base fibres constant. The experiment included testing of strength and stiffness of the fabric. It was found that with increase in the content of latex the tensile strength also increased with increase in water absorbency but in contrast the stiffness slightly increased. So it was concluded that latex bonding can be vital in improving the air laid tensile strength but upto a limit because of increase in stiffness which can result in reducing the absorbency capacity [16].

xiv. **Subhankar Maity** produced a needle punched nonwoven from jute fiber and jute waste. She stated the importance of jute fibre in geotextiles owing to their high strength, good dimensional stability, high moisture absorption, biodegradability, economical and environment friendly. After producing cross laid web and bonding them using needle punching method, the samples were tested for physical and mechanical properties. With increase in mass per unit area, punching density and needle penetration the bursting strength also increased but resulted in decrease in air permeability. This high strength material is feasible to be used for reinforcement purpose in riverbank as they were capable in providing enough strength for the slope. Also the excellent water absorbency can promote the plants to grow reducing the soil migration. The biodegradability behaviour of jute helped in soil stabilisation, improving the nutrients of soil [17].

xv. **Hao Wu** with some other researchers observed the problems of geotextiles produced from synthetic fibres. They found out that even though the synthetic polymers were non-degradable during the service life of these polymers they can degrade under harsh conditions caused due to air, water and UV radiation which can create many environmental problems accounting to soil pollution due to mixing of fine polymer in the environment. So in the research he studied the recent development of geotextile mainly focusing on green geotextile using natural fibres which were beneficial over synthetic in terms of cost and biodegradability. According to the study, jute and coir fibers were the most favorable material for natural geotextiles owing to their high mechanical properties and bio-degradability. The main issue related to riverbank is the erosion caused due to wind and water and other factors. Hence for temporary protection geotextile acts as covering for soil until the vegetation stabilizes the soil. In such cases using natural geotextiles can overcome issues generated by synthetic geotextile. Also after certain time the natural geotextiles decomposes in soil itself increasing the soil nutrients creating ideal conditions for vegetation [18].

2.3 Conclusion

From the research material studied it can be concluded that there is scope to improve the nonwoven aquadesk properties by using geocomposites like jute mesh, or by using recycled polyester. This study revealed significance of natural fibers, so there is opportunity in combining the natural fibers with aquadesk to achieve better results. The field for improvisation is discussed further in the experimentation part.

CHAPTER 3

BANK REINFORCING TECHNIQUES

3.1 Introduction

Anti erosion works are carried out to protect the bank prior to the threat of erosion. Various bank protection techniques are used in the areas more prone to erosion and failure of the bank. The traditional procedure consists of building concrete walls and laying down stones which plays vital role in minimizing the water effect on the structure of the bank. The stability of the river bank mainly depends on the water flow, the amount and the momentum of water entering the bank. As the water flow is completely natural it tends to change over period of time and is unpredictable, this results in changing the shape and forms of river bank [19].

3.2 Causes of river bank failure

The main component affecting the causing of bank failure is water flow in the river bank. The technical reasons which cause the deterioration of the bank are collapse or sliding of the slope during flood time when the banks are exposed to high water level. Due to this the bank gets saturated for long duration and causes structural damage because of decrease in the shear strength of the soil also from mechanical stress acting on the banks originated from activities of humans and animals. Another cause is the constant washing away of the soil particles in the bank due to the flow of water. The eddy current inside the water causes the base of the bank to get eroded hence bringing out the collapse of bank. Different wave loads acting due to wind generated waves, waves caused because of heavy ships and boats. The stability reduction is also caused by the seepage flow in which the water fills the tiny pores in the bottom of the bank and this moves the bottom layer of the soil [19].

Following figure shows an example of a deteriorated river bank:

Figure 3.1: - Typical eroded bank [19]

3.3 General Methods for bank reinforcement

General ways representing the bank protection and avoiding erosion are discussed below:

3.3.1 General Concept

Typically, the techniques can be distinguished into direct and indirect methods;

1. Using different vegetation, constructing pavements, revetment, proper embankment, slope grading, etc comes under direct method of bank protection. These firm structures cause reduction in the total hydraulic impact acting on the bank [19].

2. While indirect methods includes river training measures that are structures intended to change the ongoing flow of river by deflection that is deflecting the water current far from the bank [19].

In case of low water current, simple vegetation techniques are used where special high tensile strength grass like Vetiver is used. It is a long grass having high strength [19].

Also other vegetation cover like shrubs and willows can be used for bank protection. While for the areas with high water flow definite structural bodies are used for example stones, concrete blocks, geobags and geotubes filled with sand and geo-textile fabric [19].

3.3.2 Traditional Methods

Some of the traditional and efficient methods for reinforcing the river banks are discussed below:-

a) Vetiver

Vetiver is a type of bunch grass usually tends to grow in tufts or in group. According to the study these grass can grow upto length of 3 meters long while they are also known and used for their longer roots which can grow upto 3 to 4 meters. This extraordinary length of the roots leads to having great tensile strength of around 75Mpa.They have a tendency to live upto 5 months in 14 meter deep water which makes them to survive them in extreme conditions making them favourable for under water protection [19]. Following shows the river bank structure difference before and after installing vetiver:

Figure 3.2: - Bank before the vetiver implantation [19]


Figure 3.3: - Bank after the vetiver implantation [19]

The main advantage of using vetiver grass is the low construction cost and lower maintenance requirement [19].

b) Vanes

These are underwater permeable kind of protection structure used to redirect flow. In this the vanes are situated at an optimum angle and height with the bank in order to improve the water stream and prevent bank erosion. The orientation and placement of these vanes is decided by studying the river channel [19]. A pictorial example of submerged vanes is shown below:

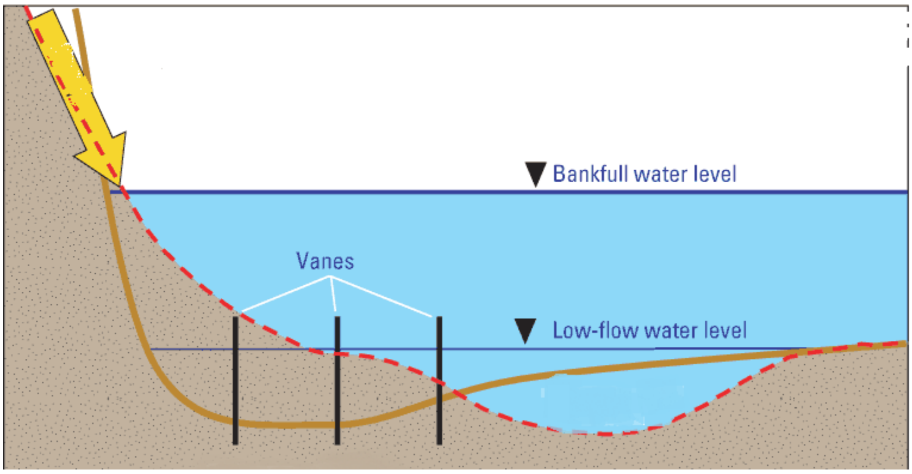

Figure 3.4: - Bank profile after using vanes [19]

3.4 Geo-synthetics as reinforcement

To provide protection for the slope and the bank of river numerous methods were applied but were proved costly and were not enough efficient. The introduction of geo-synthetics in the application for river banks is considered as cost effective, durable and easy to implement [20].

3.4.1 General

With research and technology it was proved that textiles can be beneficent when they are to be used in civil engineering. One of the factor that the textiles are been developed for is reinforcement. These geo-synthetic materials serves as a reinforcing material when used with soil, they tend to increase the strength and composition of the soil layer. Some of the major applications in which these materials are been used are river embankment, soil walls, reinforced soil slopes, etc. For flood management applications, geo-textile bags, geo-textile tubes, geo-textile membrane are used. These materials provide a firm structure to the river bank by adding strength to the soil [20]. Following shown is the reinforcement work done by geotextile when used in soil-

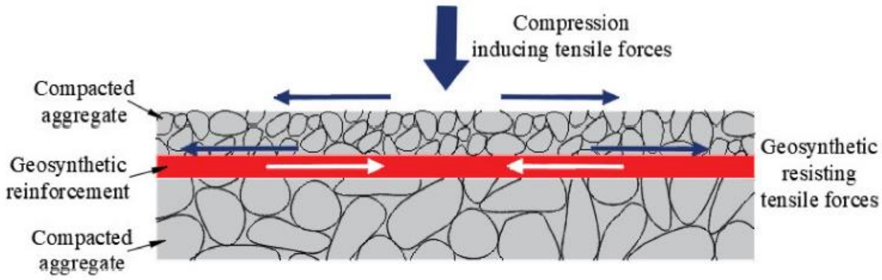

Figure 3.5: - Reinforcement function of geo-textiles [20].

3.4.2 Need for geo-textile in river bank

In earlier days, mainly firm structure materials like stone and concrete blocks were used for protection of the bank. But eventually, they were not quite efficient because there is regular interval change in the water level of the river bank. This causes seepage on the bank slopes, which is flow of soil particles in and out. Thus these stones and concrete blocks the seepage flow which leads to develop pore water pressure which is the pressure of water held within soil or rock [21].

So this pressure causes destabilization of the bank slope. Another bad effect was undermining of soil particles because of removal of soil particles [21].

The protection was required not only on the sides and slope but also to the base of the river called river bed. Generally sand bags, wire mesh mattresses, concrete blocks are used at the river bed, but during high flow fine soil particles are washed away causing erosion of the bed. Therefore there was a need to provide a filter material below these materials to ensure proper protection. This filter material in the form of geo-textile was developed water permeable while opposing the flow of fine soil particles through them [21].

The basic design requirement of the geo-textile should give:

a) Adequate water permeability to allow free movement of water without developing any stress on geo-textile fabric.

b) Adequate filter capability to avoid the loss of soil.

c) Fabric should be able to sustain the forces acting upon during installation and its service [21].

Geo-textile can be manufactured in both woven and nonwoven form. Varieties of fibers from natural to synthetic are used in making of geo-textile fabric. Woven geotextile serves mainly for separation while nonwoven geotextile are used in the application which requires high filtration capability and providing reinforcement [21].

3.5 Design method for using Geo-textile in river bank

To use geo-textile for the protection of the river banks they need to meet specific requirements such as having high strength and elongation properties, having adequate filtration capability, must be durable throughout its usage.

3.5.1 Mechanism of filtration

The geo-textile has to be capable of avoiding transfer of soil particles and must be able to allow free movement of water between its layers [21].

Therefore filtration can be summarised by having two requirements:-

a) The fabric must hold the soil particles which can be only achieved when the largest pore opening of the fabric is smaller than the specified maximum value of soil.

b) Enough permeable to allow the flow of water stating that the openings are large enough and in sufficient number to permit water flow that too without clogging [21].

3.5.2 Design of geo-textile fabric

The important parameters considered before finalizing the fabric are:

a) Retention: Holding of soil particles by making sure the opening are enough small to prevent the relocation of soil.

b) Permeability: Making sure to allow the water to pass avoiding any pressure build-up.

c) Staying power: Making sure the fabric is strong enough to oppose damage during installation

d) Service life: Making sure the fabric is durable and has resistant properties against environmental effects.

e) The study of above parameters with actual site conditions helps in deciding the right kind of material [21].

3.5.3 Specification of geo-textile

Geo-textiles are permeable material generally made from synthetic polymers like polyester and polypropylene. Among the natural fibers, jute is famous for its strength and eco-friendly nature. They are manufactured by using either woven or nonwoven technique into strong sheets [21]. In this thesis we are going to concentrate on polyester made nonwoven fabric.

In nonwoven technique, the fibers are randomly distributed by using filament or staple fibers and are bonded together using various techniques like chemical, mechanical and thermal [21].

3.6 Installation of geo-textile

Before applying geotextile at the bank there are certain measures that are required to be carried out. From preparing the ground before the geotextile fabric is rolled out to proper storing of fabric are important factors to avoid any error which may lead to failure of the main cause which is protection of the bank. First the land has to be cleaned to remove any foreign material and sharp objects; the fabric has to be rolled out carefully and must be fixed to the ground by proper means [21]. The simple installation procedure is shown below: -

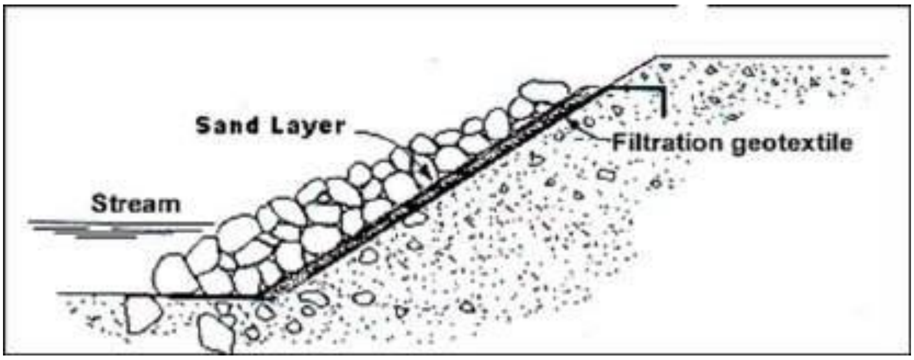

Figure 3.6: - Typical Geo-textile Installation Procedure [21]

3.6.1 Ground preparation

Initial preparation of the ground includes clearing the site of any objects such as large rocks, willows, wooden logs as they tend to damage the geo-textile when rolling out. Any present holes on the ground or dug out places on the slope of bank should be filled with suitable material, generally sand. The site should be levelled before laying the geo-textile. Soil proofing uses a vibrating compactor to compact the soil to avoid any deformation of surface. Unsuitable sub grade which is layer of soil compacted for loading heavy structure, should be replaced with suitable material before installation [21].

3.6.2 Laying the Geo-textile

After the site is levelled out and cleared of any undesired substance, the geo-textile fabric is rolled out on the surface keeping it tight enough to keep minimum wrinkles but at the same time allowing it to acquire the shape of the surface [21].

Presence of wrinkles or any folds will not provide enough reinforcement to the ground. It should not be exposed to UV deterioration for more than one week in case of untreated geo-textile while for treated fabric this should not exceed 30 days. Geo-textile should be rolled out in correct direction as decided according to the plan. Appropriate cutter should be used to cut the fabric and adjoining sheets of fabric are to be overlapped. This has to be done to the overall site of application. To fix the fabric; staples, sandbags, pins or any other material approved by engineer is used. For securing the fabric, steel pins of 15 to 45cm length are used. In areas of loose soil even longer pins are used [21].

The part of fabric that got punctured while fixing it to the ground should overlapped by new layer of geo-textile, ensuring there is minimum overlap of 1000mm between edge of damage and overlapping patch. While laying of fabric it is necessary to make sure that one continuous roll is installed. Whichever part of the geo-textile is pending to be worked should not be left exposed and has to be wrapped by using covering roll. After the layer of geo-textile has been placed, it needs to be covered with suitable pitching such as stones, sand, sand bags, etc [21].

For applying geo-textile underwater, care has to be taken so that the fabric is laid for the entire length of the apron or area to be applied. Avoiding any gaps between adjacent rows, in case of any gap it is necessary to place a sufficient overlap with upstream sheet overlapping the downstream sheet in order to give erosion protection. It is of great importance that while placing the fabric underwater the water flow should not exceed 1.5-2.0 m/s. For water flow above, the end of the geo-textile is carried upstream of appointed place as because of water flow the fabric gets carried away moderately downstream. Loading can be done by dumping sand filled bags to fix the fabric to the bed [21].

3.7 Role of vegetation in reinforcement

Use of vegetation techniques have proven to be economically beneficial, eco-friendly, self-repairing and durable for problems concerned with slope and helps in improving the riverbank stability. Till now mechanical methods in reinforcing the river banks have been proven efficient and show instant effect. But the only drawback shown was the price to construct these structures and to keep it working [22].

Hence alternative remedy using biological methods like developing vegetation i.e. allowing plants to grow and to perform same function as concrete structural did. This alternative method has been proven comparatively cheaper given slower working effect but once they planted they tend to show steadily improving but consistent control of erosion [22]. When vegetation is used in river slope, the soil clay content increases with helps in bonding of the soil structure and which results in improving the resistance of soil against erosion [23]. The soil erosion control mechanism by plants is caused when the stem and root of the plants links with the soil particles migration. The usefulness of plants in reinforcement is greater as whole plant serves in protection of the bank. The top part of the plant above the ground also called as canopy transforms the distribution of the water droplet and it causes reduction in the dropping speed of the drop resulting in minimizing the kinetic energy available for erosion. It is more effective during heavy rainfall [22].

The roots of the plants are capable to alter the attributes of the surface soil, they also helps in improving the shear resistance of soil against the flow of water. In some species with long roots, they can penetrate much deeper and reduces the chances of mass migration of soil [22, 23].

Finally, the stem helps in breaking the overland flow and resists, causing reduction in the flow velocity and transport of soil particles. This vegetation can be used with geo-textile material for better stability of the river bank. Some specific geo-textiles manufactured having high water retention properties are favourable to cultivate plant of the surface of the fabric. Hence the combined strength of vegetation and geo-textile fabric can help in achieving better bank stability [22, 23].

3.8 Erosion Control mat

Important factor for vegetation i.e. high moisture can be achieved using erosion mat. These mats are used as a stabilization fabric and are planned to support plant growth and reinforce soil. Both natural and synthetic materials are used for making the erosion control mats. These mats are able to support banks until vegetation is able to take root. They are manufactured in both degradable and non-degradable type. For short term erosion control, biodegradable mats made from coir or straw fibbers are used [19].

Non-degradable mats are made from polypropylene fibres and are point bonded together thermally to gain extra dimensional stability [19].

Figure 3.7: - Erosion control mat [19]

3.9 Aquadesk

Another kind of non-woven geo-textile fabric used for vegetation is Aquadesk material. Aquadesk is a fabric plate used basically on the roof of houses. This fabric serves as a green roof having greater absorbency, retention, mechanical and other essential properties. This material is manufactured using recycled polyester fibres [24].

These fibres are further connected together by using bi-component fibers and are thermally bonded by using hot air. The main features of using aquadesk are that it is completely recyclable. Excellent absorbency and retention properties of aquadesk make them favourable to be used in riverbank for reinforcing. The conditions are good for the vegetation to be grown on the fabric and can be long lasting owing to higher mechanical properties of the material. Usage of recycled polyester for the production of the fabric makes them to be produced at a low cost. Hence in all ways considering cost, eco-friendliness and also performance wise aquadesk can be proved as a modern solution to the riverbank protection [24].

Figure 3.8: - Aquadesk Material [24]

3.9.1 Advantages of Aquadesk

a) Easy Installation: - Material characteristics and its nature allow it to be installed without any difficulty and no technician is required for the installation so any person can install this material.

b) Drainage Retention: - It refers to collection and holding of water. After testing, 40mm thick aquadesk at inclination of 10 degree it was proved that it can hold up-to 20 litres of water per square meter.

c) High mechanical properties: - When tested for mechanical damage i.e. puncture test, it was found that 40mm material gave the best results against all mechanical effects.

d) Eco-friendly: - Aquadesk is composed of recycled fibers and without using any chemical substances.

e) Economical: - Use of recycled fibers allows reducing the cost of material. Aquadesk is planned so its economic advantages are greater than its cost hence high use value can be achieved by aquadesk.

f) Insulation: - Aquadesk has been proved as good for noise and thermal insulation. With that the vegetation formation also protects the roof from sun [24].

3.9.2 Handling of Aquadesk

a) Storage: - Before installation the aquadesk should be stored in a closed place or under a roof and must be kept dry to protect it against rain. Wet panels are remarkably heavier which makes it difficult for handling during installation.

b) Cutting: - It is preferred to use a special knife or a power saw for shaping the aquadesk according to need. Since the material is extremely strong, using an ordinary knife will deteriorate the material and also aesthetics.

c) Overlaying: - In case of multiple layers it is necessary to cover the joints of the bottom layer. Minimum overlapping is required for better performance and to prevent the dirt entering into material.

d) Fastening: - With a slope less than 15 degree there is no need to fix the material while for higher degree of slope the aquadesk panels should be fixed to the base [24].

CHAPTER 4

NON-WOVEN

4.1 General

The whole purpose of using nonwoven fabric was its strength, performance behaviour under high load and also they were determined as low price substitutes for conventional textiles. Various methods and materials are used with distinctive properties to achieve the required results. When used for reinforcement, the nonwoven fabric must have good mechanical, filtration and chemical properties. These properties help in achieving the required working effect. For these requires proper selection of raw material, process of manufacturing and determining application of the fabric on actual working site [25].

4.2 Non-woven

Nonwoven fabrics are products made of parallel laid, cross laid or randomly laid webs bonded with application of adhesive or thermoplastic fibers under application of heat and pressure. According to European Disposables and Nonwovens Association (EDANA) nonwovens are defined as “A nonwoven is an engineered fibrous assembly, primarily planar, which has been given a designed level of structural integrity by physical and/or chemical means, excluding weaving, knitting or paper making”. First the fibres are oriented in a directional or random way that are laid down in form of web and then bonded by using various techniques [25].

The nonwoven fabric properties mainly depends on following

1. Fibres

2. Technology determining how the fibres are to be arranged

3. The bonding process and bonding agent [25]

4.3 Classification of Non-woven

The main three methodologies for making nonwoven are explained below:-

1. Dry laid- In dry laid technique, the fibres are carded (using roller carding or cross-lapping) or formed aerodynamically i.e. Air laid and then bonding of the web is done. Mainly bonding methods used are mechanical bonding (needle punching, stitch bonding and hydro entanglement) or thermal bonding or chemical bonding [26].

2. Wet laid- Wet laid is a development of paper making process. In wet laid the fibres dispersed in water are placed onto a forming surface like wire cloth to form a web with further drying and batching up the web. To differentiate wet laid nonwovens from wet laid papers, if the fibrous web has more than 50% by mass of textile fibres then it determined as wet laid nonwoven [28].

3. Polymer laid- In basic polymer laid process, sheets of synthetic filaments are extruded from molten polymer onto a moving conveyor to form a randomly oriented web in the closest approximation to a continuous polymer to fabric operation [28].

4.4 Production of non-woven:

Production of non-woven is done in three main stages

- Raw material supply: - The selection of fibre depends on the final application. According to the requirement of the fabric the fibres are to be selected. Type of fibre i.e. Synthetic fibres, natural fibres and their properties affect the final product [26].

- Web formation: - It is considered as the initial stage in production of nonwoven fabric. In this step the prepared fibres are laid on each other to achieve the required amount of fibres in certain area which forms the web or batt of fibres. Various methods are available in market for formation of web depending on application [27].

- Web Bonding: - The fibres are loosely packed after the web is formed, hence it is necessary to bond the web so the fibres are connected together. It is achieved by mechanical, thermal or chemical process. The main objective of bonding is to introduce strength into the web [26, 27]

4.5 Raw Material: -

In nonwoven all kinds of fibres can be used for manufacturing the fabric. The choice of fibre mainly depends on the application of fabric and cost effectiveness (Cost/use ratio) [28].

Since nonwoven fabrics are primarily produced considering the end application and to meet the required need, it is of foremost importance to choose the correct fibres. Not only the kind of fibres but also their properties are taken into consideration. For the production and development of nonwoven fabric it is necessary to study the properties of all fibres [28]. Some commercially used fibres in nonwoven industry are

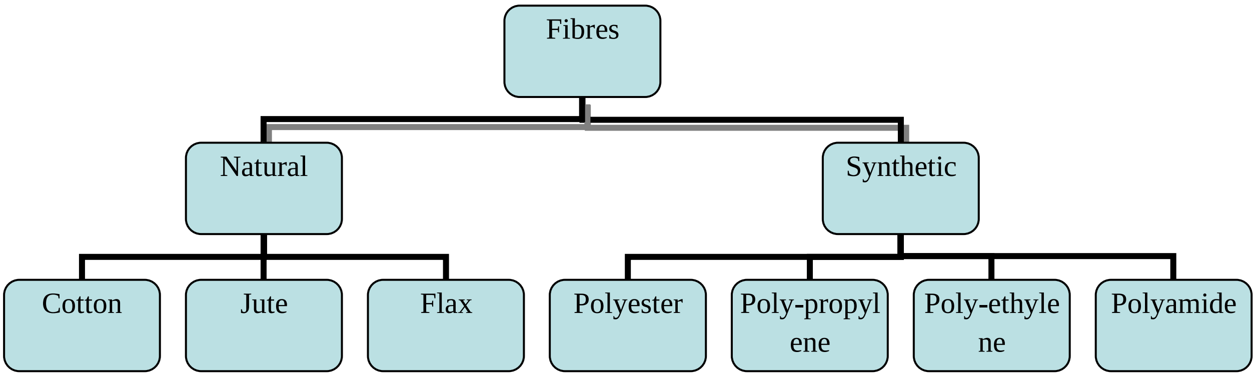

Figure 4.1: Commercially used fibers in nonwoven industry [28]

Synthetic fibres dominate natural fibres completely in nonwoven production. Most commonly used polymers for production of nonwoven are polypropylene and polyethylene. But when high strength is required, polyester is most favourably used. Quantity i.e. readily availability and economic behaviour are the important factors to be considered for production of any nonwoven fabric. Since some polymers are not readily available in large volume and are be likely costly, polyester has proved optimum while considering the price to performance ratio [28].

Polyester is also commonly known as polyethylene terephthalate. From the name it is clear it consists of macromolecules of esters. Ester being the main functional group is composed of acid and alcohol. These primary molecules are joined together to form polyesters. Generally polyester is produced from a process called polymerization [28].

In this process, ethylene glycol and terephthalic acid are heated together in the presence of catalysts [28].

This reaction results in formation of molten and viscous polyester which can be further spun directly into fibres or can be solidified into chips for later use [28]. The reaction for the polyester formation is given below:

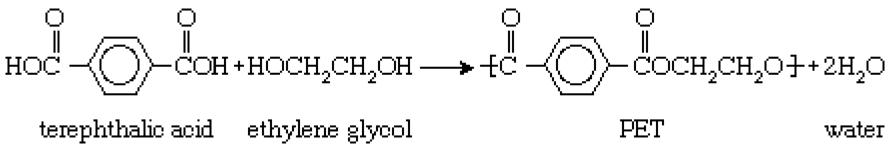

Figure 4.2: - Chemical reaction for polyester formation [29]

In this reaction, the alcohol group from ethylene glycol consists of two hydroxyl (OH) groups while terephthalic acid consists of a large carbon ring and two carboxyl (CO_2H) groups [29].

In the presence of heat and catalysts, these carboxyl and hydroxyl group reacts to produce ester (CO-O) groups. This ester group acts as a linking agent between multiple PET units together to form a long chain polymer. Below shown is the chemical structure of polyester [28, 29].

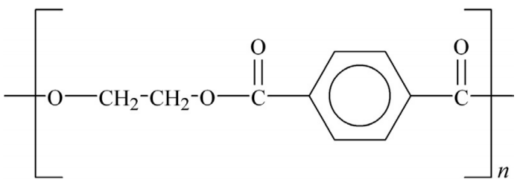

Figure 4.3: - Chemical Structure of Polyester [30]

The microscopic view of polyester fibre is shown below:

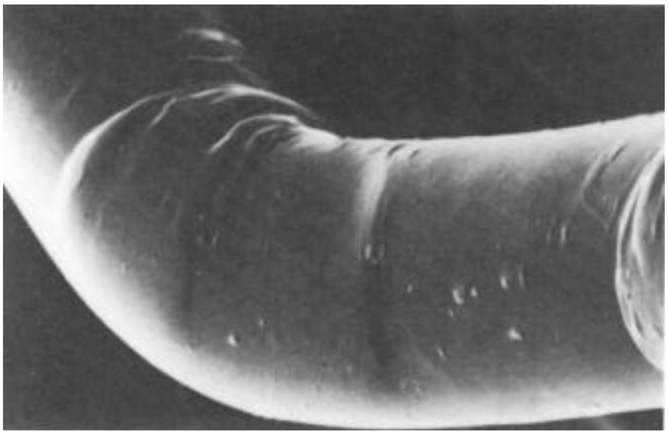

Figure 4.4: - Scanning electron microscope photograph of a PET fibre [28]

Some of the important properties of polyester are discussed below:-

A) Physical Properties

i) Mechanical Properties: - Depending on the method of processing, a wide variety of polyester fibre properties is possible. In general, as the degree of stretch is increased, resulting in greater crystallinity and greater molecular orientation, so are the characteristics, such as tensile strength and Young's initial module. Elongation usually declines at the same time. Tensile strength, modulus, and extensibility are further improved by an increase in molecular weight. Generally, the tenacity lies between 5-7 gram per denier while elongation at break between 15-30%.

ii) Moisture regain: - Polyester moisture regain is low, varying from 0.2 per cent to 0.8 per cent.

iii) Specific gravity: - Specific gravity is generally around 1.38.

iv) Heat effect: - The melting point of polyester is close to that of polyamide, which ranges from 250 to 300°C. Polyester fibres, leaving a hard black residue, shrink from the flame and melt. A heavy, pungent odour is developed after burning [31, 32].

B) Chemical Properties

i) Effect of acid: - Polyester fibers have excellent tolerance to strong and weak acids at room temperature. Extended exposure to boiling hydrochloric acid deteriorates the fibers and 96 per cent of sulfuric acid and allows the fibers to disintegrate.

ii) Effect of base: - Polyester has good resistance to alkalis in cold conditions but at boiling temperature it gets dissolved in NaOH.

iii) Miscellaneous properties: - Polyester fibers exhibit good resistance to sunlight, and are also highly resistant to abrasion. It is not damaged by soaps, synthetic detergents and other laundry aids. One of the most serious polyester defects is its oleophilic quality. It easily absorbs oily materials and holds the oil tightly [31, 32].

4.6 Web formation

Web formation is the first step in the manufacturing of any nonwoven. In this process the fibres or filaments are laid on each other to form a layer of web. The objective of web formation is to convert the fibres into a web like assembly [26].

The main parameter of a web is its structure and it will have a strong impact on the dimensions and properties of the final fabric [26, 28]. The web formation is split into following ways:-

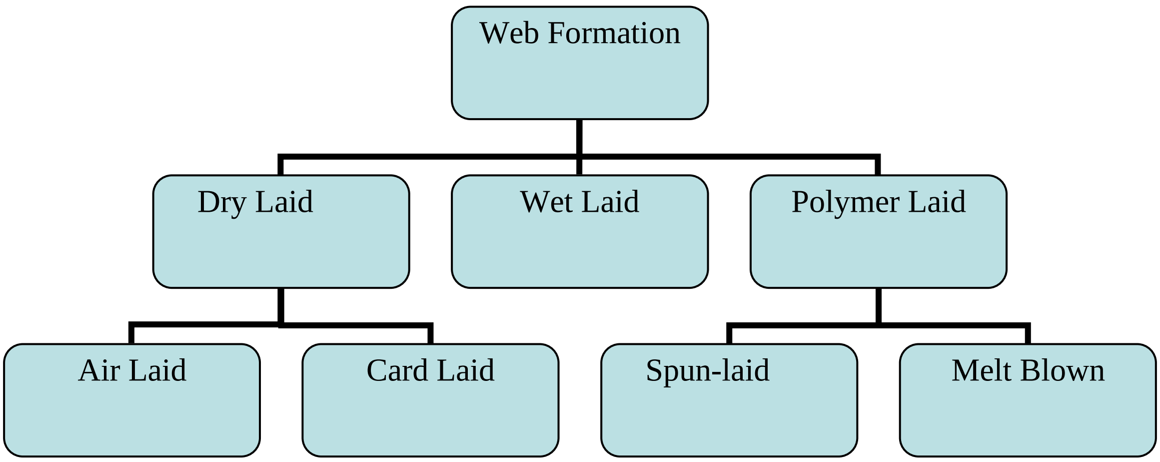

Figure 4.5: Web formation Technique [28]

Air-laid

The typical process for producing nonwoven from air laid technique is given below

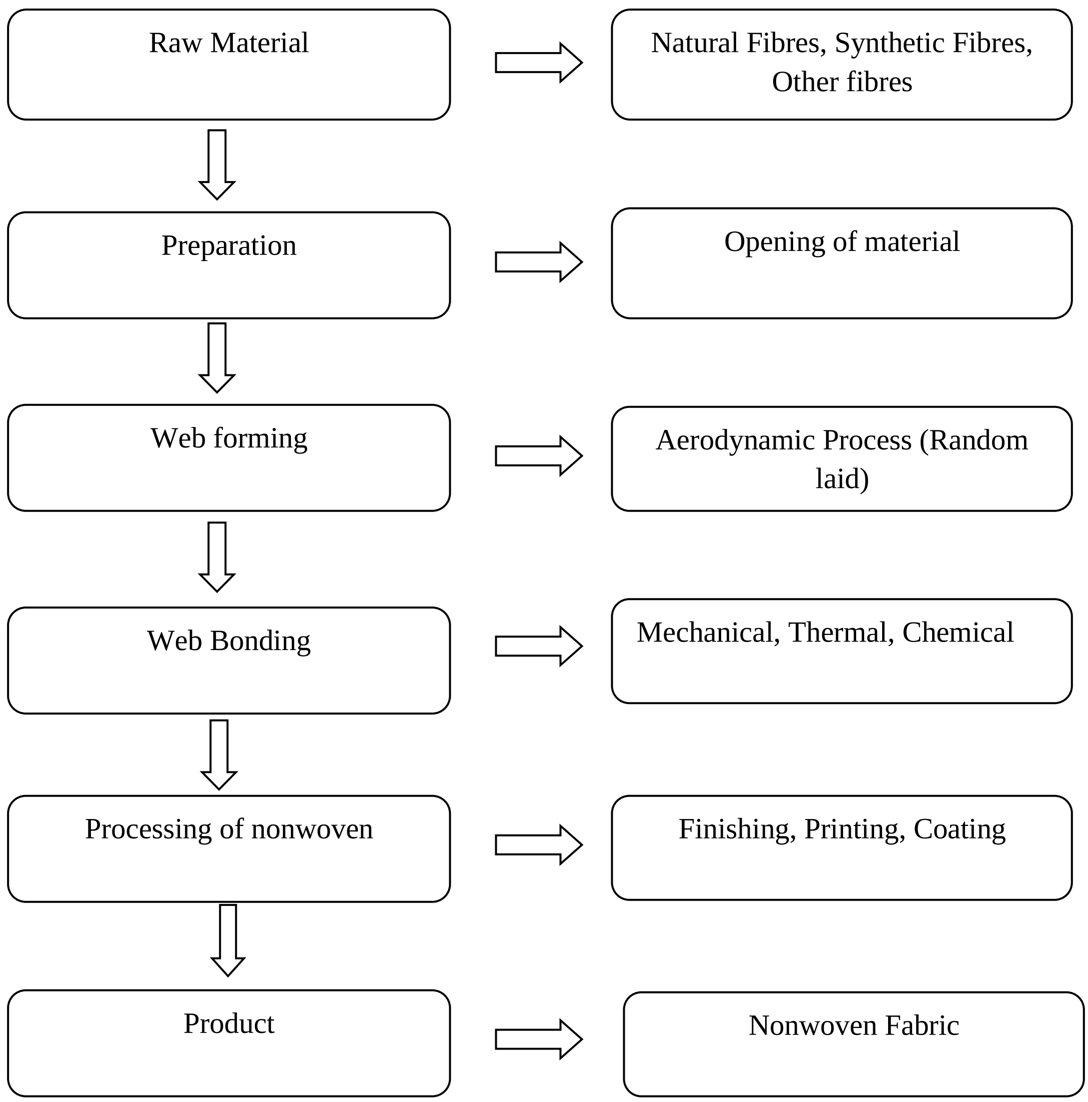

Figure 4.6:- Typical air-laid process [28]

Air laid process is also referred to as aerodynamic process as the fibre laying process is carried out by air hence the fibres are laid completely random. The main characteristics of air laying web is its isotropic nature. This process falls under dry web forming process in which the fibres are intensively more or less opened before web formation [27].

The degree of fibre opening may differ between the machine manufacture but is always less than as compared to carding. This method of web formation allows them to be used for variety of fibres because of the principle of transport of fibre and deposition and different machine designs available. It is necessary to implement open and ideally individualized fibers to the airstream so that uniform web is produced without any inter tangled fibres or clump [28].

The opening procedure in airlaying consists of machine line same as that of used in carding. The basic machine line used is bale breaker, coarse opening machine, fine cleaning machine, mixing and blending and a metal detector. The bale breaker breaks the large bales of fibres into fibre tufts which are feed to a coarse opening machine which breaks the tufts and also performs cleaning mainly removing any dust particles and foreign material. Then the fine opening machine uses cleaning rollers with needle spikes on it to open the fibre further and removing the micro-dust. Then the material is passed into a large blending machine where the fibres from different machines are stored in different chamber and are well mixed to produce a homogenous material. Later the material is passed through a metal detector to detect and remove any metal objects such as wire, screws, spikes and any unusual object [28].

The principle of air laying is quite simple involving feeding of individual fibres into the air stream and allowing the air stream to carry the fibers towards a permeable screen or a conveyor where while separating the air, the fibres are randomly deposited to form a web [26].

The simple air laying principle is shown below:-

1. Pre-made batt
2. Feed rolls
3. Main cylinder
4. Air blower
5. Suction
6. Conveyor belt
7. Air laid web

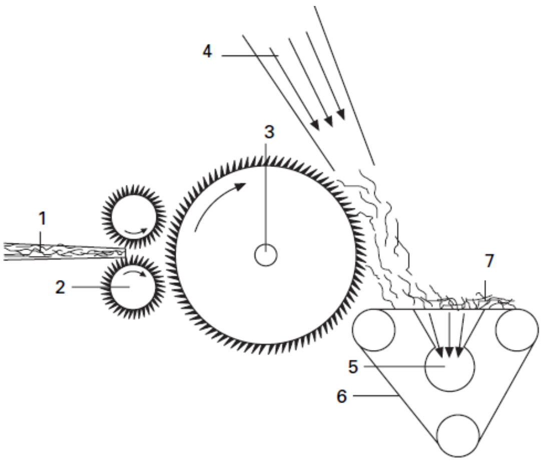

Figure 4.7: - Principle of simple airlaying process [26]

In this design, the pre-opened fibres from the fibre preparation process if uniformly fed to the pair of feed rollers. The fibres are then fed to a high speed rotating cylinder or a roller having pointed spikes on it. The clamped feeding of fibres by the feed rollers allows the cylinder to open up the fibres and the wires or spikes on the roller helps the fibre to easily transport on the cylinder and are further removed by a strong air stream that dislodges the fibres from the surface and carries the fibres and are deposited on a permeable conveyor where the air is separated from the fibres using suction and the web is formed. Various systems and machine design are available in market for air laid process. The properties of final web material changes accordingly to the method used. The parameters influencing the web properties are amount of material fed, air flow in the transport chamber, density of the web and fibre properties [26].

4.7 Web bonding

After a web is made it is not strong enough to be directly used for application as the fibres are still loose and are not connected with each other by any means other than minor inter frictional force between the fibers. Hence it is vital to bond these fibres together by using appropriate techniques. Web bonding is a process in which strength is imparted inside the web to make sure it meets the necessary performance parameter for the application. The level of bonding depends on the fibre parameters like its geometry, strength, its position in the web and mass of web [27].

The bonding of web is achieved by either chemical or physical treatment. Physical bonding is achieved by imparting strength by entanglement of fibres/ filaments caused by friction and cohesion, while in chemical bonding; binding agents are used [27]. The figurative presentation of web bonding is as follows:-

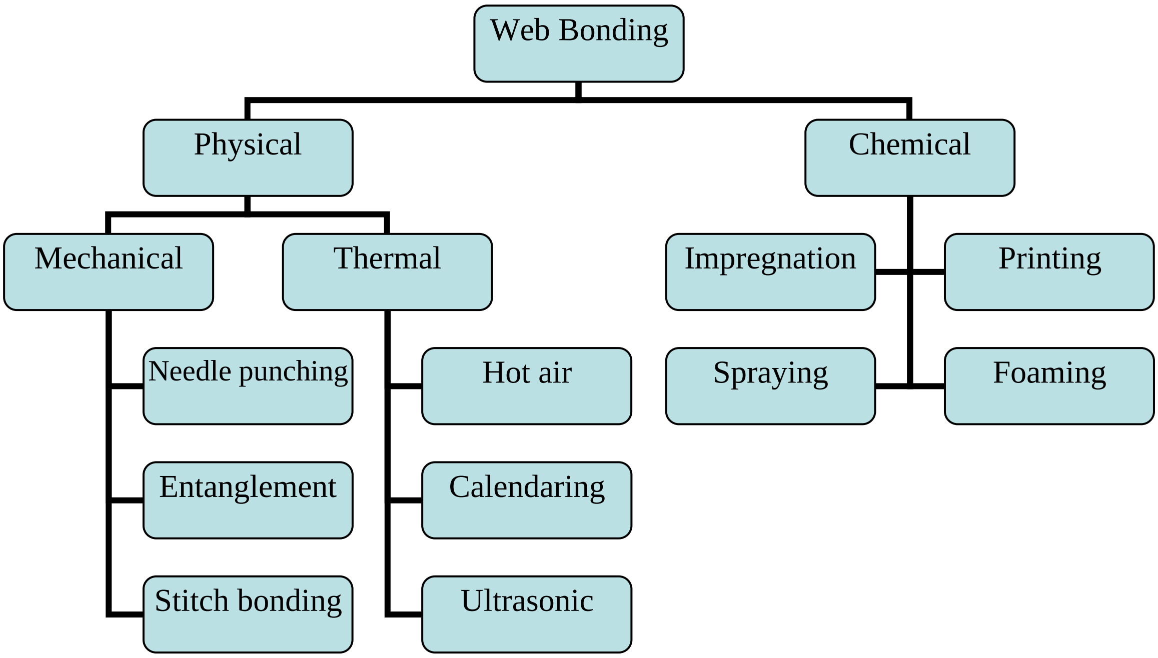

Figure 4.8: - Web bonding technique [28]

The mechanical and filtration property of fabric depends on method and degree of bonding technique. Among the various bonding technology, commercially used method in producing geo-textile are mechanical and thermal bonding [28].

Thermal Bonding: - In thermal bonding, a thermoplastic component is used in form of a bicomponent fibre, powder or film. Mechanism is to apply heat to the web until the thermoplastic component melts or becomes viscous. The bonding regions are formed from fibre to fibre by the flow of polymer and are further fixed by cooling that solidifies the bonding area [26, 28]. Thermal bonding is further classified as

a) Calendaring

b) Through air bonding

c) Ultrasonic

The basic principle of thermal bonding is that during the web formation according to the required property of fabric certain ratio of thermoplastic component is added. The thermoplastic material melts or becomes viscous and gets fixed by cooling. When the binder material i.e. either bi-component fibres or powder melts they tend to flow into the web and also around the fibres. This leads to formation of bonding points over the web, both on the surface and throughout the thickness. After cooling, at these bonding points forms a mechanical bond between the fibres in the web and the thermoplastic component [28].

The binder material exists in various forms like bi-component fibers or powder, film, low melt webs, etc. The formation of binding points is mainly governed by physical form and distribution of the binding material throughout the web. This distribution has a remarkable impact on the web properties [26, 28].

In our thesis we are going to produce the fabric using hot oven thermal bonding technique and utilizing bicomponent fibres as a binding agent. The production technique of bicomponent fibres includes extruding two different polymers from the same spinneret but the both polymers are within the same filament. To bring out a certain capability not containing in either of the polymer is the main objective behind producing the bicomponent fibres. This allows us to make these fibres with a carious cross section and geometry [33].

The classification of these fibres can be done as sheath-core, side-by-side, etc. In short the properties of bicomponent fibres are characterized by;-

-the two polymer used
-the quantity of the polymers present
-the arrangement of polymers
-thickness of fibre

The fibres are made up of fusible thermoplastics such as polyethylene, polypropylene, polyamide and polyester. In this, the polymer with low melting point either wraps the whole surface of the polymer having high melting point i.e. core and sheath or in side by side both polymers are extruded together. During bonding, when the produced web is subjected to heat, the polymer with low melting point becomes viscous and migrates between the web forming bonding points whereas the polymer with higher melting point conserves the fibre shape [26].

Popular polymer composition in bi-component fibres are:-

- Polyester Core and Polyethylene Sheath (Melting point 250°C and 130°C respectively)

- Polypropylene Core and Polyethylene Sheath (Melting point 175°C and 130°C respectively) [26]

After the web is formed through hot air the web is bonded. This can be done in two ways by using either a perforated drum or a perforated conveyor/belt. In a belt perforated through air bonding of nonwoven; air jets are used to blow hot air through web. A set of nozzles are situated that blows hot air onto the web. Depending on the bonding required these nozzles can be used on one or both sides of the web [26].

A simple arrangement of through air bonding on a perforated conveyor is shown below: -

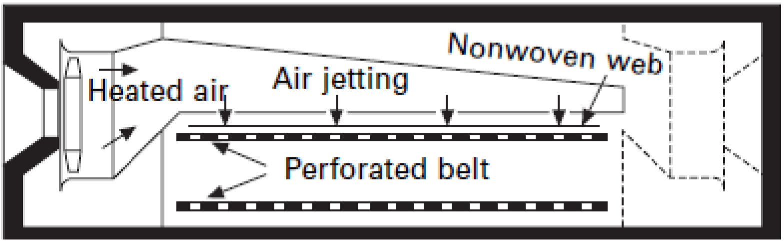

Figure 4.9: - One-sided air jetting system [26]

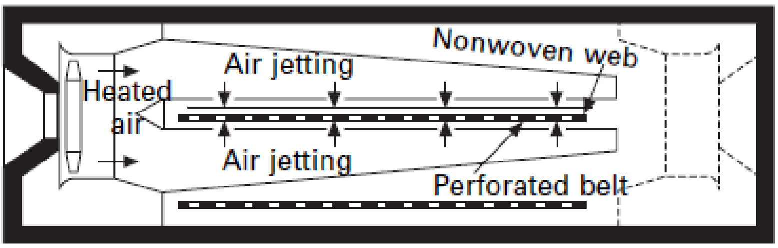

Figure 4.10: - Double-sided air jetting system [26]

CHAPTER 5

EXPERIMENTAL PART

5.1 General

The thesis will be explained on a theoretical basis including detailed explanation of methods of protecting riverbank, main focus will be on Aquadesk and use of vegetation. Also plan of work for the thesis will be discussed theoretically. The reason behind the explanation of thesis on presumption is the unpredictable situation occurred due the ongoing worldwide pandemic. Due to the countrywide lockdown in Czech Republic and restrictions, according to government rule students were not allowed to visit lab in the university and perform the experiments.

The experimental part of the thesis is devoted to producing a nonwoven fabric which can be used in reinforcing the river bank. The main objective of the fabric will be to serve as barrier between land and water in the bank and to promote vegetation to introduce natural way of protecting the bank and reduce the soil erosion.

Discussion will be focussed on manufacturing of aquadesk, steps in using aquadesk as a reinforcing agent, expressing the essential properties of fabric and considering methods to fortify the existing aquadesk by different means.

5.2 Objective

i. Production of nonwoven aquadesk fabric
ii. Discussing important properties
iii. Different methods for improving aquadesk performance

5.3 Material and Methods

In this step we are going to discuss about the raw material i.e. fibres needed for the production of nonwoven fabric. Also other additional fibres needed for bonding purpose and steps for manufacturing.

5.3.1 Fibre selection

Selection of fibre was the foremost important thing. Recycled polyester along with PET fiber flakes were selected to produce nonwovens. The reason behind selecting recycled polyester is given below:-

i. They have properties similar to virgin polyester and are reusable.

ii. Reduction in carbon and other toxic emissions

iii. Prevents plastics material from decontaminating the surrounding [14].

5.3.2 Manufacturing of nonwoven

Following is flowchart displaying steps in production of nonwoven

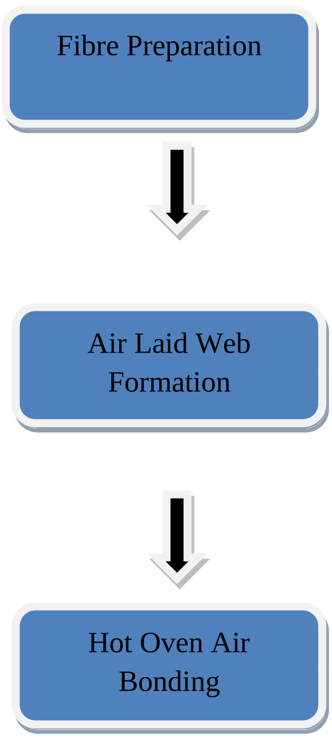

Figure 5.1: Steps in production of nonwoven

i. Fiber Preparation: - The fibres are to be prepared according to the procedure explained in CHAPTER 4 under section 4.6.

The raw material has to prepared and mixed with required amount of bi-component fibres. Recycled polyester fibres, Polyester fiber flakes and bi-component fibres were the main composition.

ii. Web Formation: - Web formation is done by using air laid method to produce a random laid web.

iii. Web bonding: - After the formation of web, thermal bonding method is used to fuse the fibres together. With bi-component fibres, latex is also used for bonding. The increase in proportion of latex helps in improving the tensile strength and water absorbency with only limitation is with increase in latex, the fabric becomes stiffer and after a point the water absorbency starts reducing [16].

5.4 Nonwoven Testing Methods

The Nonwoven Aquadesk when to be used in riverbank goes under tension as forces are acting upon it right from the material is rolled out for installation and also during their service in riverbank. So it is necessary to analyze the properties of nonwoven fabric to interpret proper behavior of fabric in riverbank and for better serving of the cause i.e. reinforcement.

Following are the important properties to be analyzed:

i. Tensile Strength: - This property of the fabric decides the maximum load that a fabric can tolerate. When the nonwoven is used as a reinforcing element it is expected to under come number of stresses. Initially it comes under stress during the installation process where heavy machinery are used for the installation, after installing the fabric is exposed to constant forces acted due to movement of water and wind, also due to human and animal activities, floating debris, etc [28].

In the testing procedure of nonwoven for tensile strength and elongation, the fabric samples are first prepared according to standards and are subjected to force until the fabric is ruptured [28].

The reading gives the data about the load experienced by the fabric along with percentage of elongation which is maximum point of elongation at which rupture takes place [28].

Standard: - ISO 9073-3:1992-08

Test conditions: - Width of sample: 50mm
Gauge length: 200mm
Loading rate: 100mm/min

The tests are carried out both in machine and cross direction. During the testing, the fabric samples are cut according to the test conditions above. The width of the sample is clamed between the jaws and force is applied until the sample tears and then the tensile force (N) and elongation at break (%) is determined [28]. The standard testing equipment at the university is shown below:-

Figure 5.2: - Tensile Strength Testing at Technical University of Liberec

ii. Water absorbency test: - When the geotextile fabric is used for reinforcement at the slope where it comes in contact with water and soil. It is necessary for any geotextile used for reinforcement to allow water pass through it preventing any pressure formation. For this purpose it is necessary that the nonwoven has good water absorbency. Also the water absorbency test helps in deciding the vegetation to be planted on the material which helps in imparting strength in the soil. Thus the material should attain good water storing ability which also helps in providing key information about stability of the soil structure, movement of water, etc [11].

To carry this test in simple way the nonwoven fabric is immersed in water for 24 hours and weighed at W_w and is then heated in an oven for certain time and is again weighed as W_t where t is drying time of nonwoven [13]. The formula used for water retention is given as: - Water retention= $\{(W_w-W_t)/W_w\} \times 100$ %------------------eq (2)

iii. Dynamic Perforation: - Geotextile nonwoven as a strengthening agent in riverbank is in constant contact with soil and water. Getting affected by external conditions like wind, water and other elements caused due to human activities makes the fabric vulnerable to malfunction. Hence it is necessary to fix the fabric to the ground by using solid elements like metallic needles or rods [34].

While installing the fabric at the bank it experiences heavy forces due to heavy machinery ending up damaging the fabric. Therefore it is necessary that the material keeps all the properties required for reinforcement. The factors affecting the resistance to puncture are the density and thickness of fabric [34].

The common test to measure the resistance of the fabric to puncture is the dynamic penetration test which is also known as cone drop test. The iso standard for carrying out the test is ISO13433:2009. The purpose of this test is to analyze the effect of the cone dropping on the geotextile. It is possible to estimate the mechanical resistance to puncture with this test [34].

The standard procedure includes a cone weighing 1kg falling from a height of 50cm vertically on a geotextile sample. The sample is placed tightly between two rings with 15cm diameter. The hole size on the sample after the testing proves the resistance of the fabric for penetration. Smaller the hole diameter, greater is the resistant to damage. [34]

The schematic view of the testing and the sample after testing is shown below: -

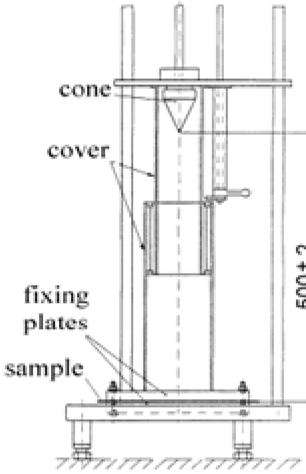

Figure 5.3: - Dynamic Puncture Test [34]

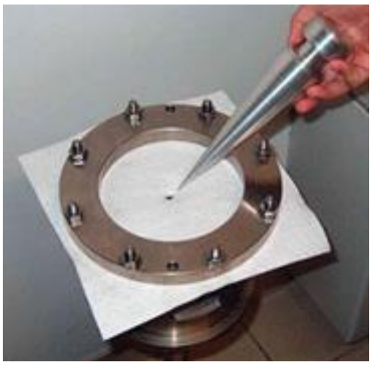

Figure 5.4: - Sample after puncturing test [34]

5.5 Scope for Improvisation

The study done in the literature review is helpful in developing the current aquadesk so that the material can show better results and perform its main objective of reinforcement of river bank. Advances in research programs related to nonwoven and geotextile has given birth to various branches and opportunities for various materials coming together to overcome the common problem of strengthening the river bank. A composite aquadesk can be produced by blending synthetic and natural fiber like jute and then bonding two mats of aquadesk by means of either stitching or fusing which can improve the water holding capacity of aquadesk [7].

Aquadesk can also be made by mixing of far- infrared fibers in appropriate proportion. This special fiber can help in the vegetation to grow faster and longer, resulting in better soil stabilization and also the increase in length can be useful in preventing the soil migration with the flow of water [10].

Aquadesk is known for its water retention properties that help plants to grow. Other approach of enhancing this property is to introduce jute fibers in the aquadesk. Jute nonwoven show better water retention property when combinedly used in aquadesk can surely improve the overall water holding capacity [12]. In another outlook low melt polyester fibers enhances the water retention so using low melt PET in aquadesk will help in further improving the aquadesk property [13].

Introducing jute mesh in between two aquadesk mats and then laminating them together can provide high durability throughout the vegetation season. Hence can be complimentary in protecting slope till the plant grows fully [15].

While bonding aquadesk the change in content of latex affect the properties of final material. Increasing the ratio of latex to optimum amount increase the tensile property upto certain level but stiffness increases accordingly. So it is important to find out the ideal ratio of latex to be used [16].

Moving towards ecofriendliness aquadesk possesses to be recycled but decomposition is hard due to presence of synthetic fibers. Since under harsh conditions these polymers can pollute the environment a path has to be found leading to produce aquadesk using natural fibers owing to green textiles which helps in reducing the pollution, better soil stabilization and all natural fiber can biodegrade enhancing the soil qualities. This modern aquadesk can stay intact till the plants are fully grown later forming compost for soil. [18]

CHAPTER 6
RESULT AND DISCUSSION

When a river bank collapses the limitless amount of water not only destroys the property and land but also possess threat to human and animal life. So different structures and particulars are used to reinforce the bank to reduce the possibility of bank malfunctioning. The information collected over the significance of erosion and failure of river bank makes it clear that the reinforcing need is of keen importance. Out of various techniques, the modern and economical way of doing this was found out to be using the nonwoven Aquadesk which till the date serve as green roof has properties that can allow humans to use them as geotextile reinforcing material in river bank. The excellent water retention properties with high strength allow them to be implanted on the slope of the bank that can encourage plants to grow. The combined role of vegetation is to restrict soil to migrate with water and to impart strength in the soil. So in such place aquadesk is preferred to be used.

The detailed study of literature made it possible to decide a correct path right from what kind of material can be used to practical, manufacturing method to appropriate way to apply aquadesk into the river bank. The study of important properties with standards helps in deciding the material specification.

Advances in the aquadesk are possible through various methods and that will help in providing even better results. Since the objective is to reinforce the river bank any possible way has to be evaluated and way has to be found out to use that in practical approach.

CHAPTER 7
CONCLUSION

The methods involved in reinforcing the river banks can be traced back to decades. Early technique included using solid structural measures to protect the river bank. It consisted of using concrete walls, using huge tree stems to breakdown the flow of water, etc. Over the period of time as humans population have migrated to live a good life and setting up their livelihood near the things that are important for survival. River water has always been a blessing by the nature as it provides fresh water for drinking and agriculture and also for industries. But prior to unpredictable circumstances like floods it is important to keep the water in a boundary and protect the riverbank to avoid disaster. Hence in order to reinforce the river bank among various techniques we have discussed the use of Aquadesk nonwoven and its benefits along with their properties.

The theoretical view explained the whole procedure right from the importance of protecting the river bank to the most effective method to safeguard the bank. The research done helped in concluding the Aquadesk nonwoven suitable for reinforcement. The literature studied assisted in finding new course of action expanding the vision to upgrade the current aquadesk to be used more effectively and efficiently. We studied the method to produce nonwoven using air laid technique and thermal bonding to build the fabric than will be feasible to be used for protection of the river bank. The experimentation part included the testing methods and equipments using standards to manufacture and decide the design and parameters of the nonwoven aquadesk. Followed by various possible methods derived from literature review to upgrade the present nonwoven aquadesk it is possible to implement the aquadesk at the river bank to serve the main purpose i.e. reinforcement. Even though the scope of the reinforcement techniques surpasses the content included in this thesis, development and research will never have a boundary.

CHAPTER 8

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LIST OF FIGURES